5B.4 QUALITATIVE COMPARISON BETWEEN THE TEMPORAL VARIATION OF STREAM FLOW INDEX AND SOLAR FLUX LEVEL: CONTINUED STUDY AND ANALYSIS

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ABSTRACT

This paper summarizes a continued qualitative comparison between daily stream flow indices of specified Continental US watersheds and the daily solar flux level. These two data parameters were initially chosen for study because the stream flow level is dependent on the cyclonic system frequency and the solar flux level is linked to cyclonic systems. In this paper the river index published by the U.S. Geological Survey (USGS) and the F10.7 centimeter (2800 MHz) solar flux are compared. An initial study uncovered a general correlation between solar flux variations and stream flow index changes. This study covered a longer period and included data from near solar maximum through approaching solar minimum. The general assumption governing the comparison discussed is: increased solar flux level intensifies cyclonic, precipitation producing, systems which, after a corresponding lag period to allow for drainage, results in increased stream flow in river systems. Thus an observed increase in the F10.7 centimeter (2800 MHz) solar flux level is expected to result in a corresponding, delayed increase in the stream flow index. A graphical summary of the data and the corresponding observations relating to the solar-terrestrial coupling mechanism are presented.

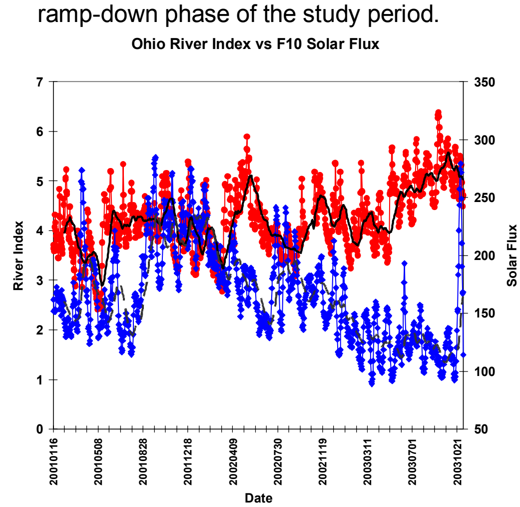
I. Introduction

This paper summarizes a qualitative analysis of daily stream flow response to daily solar flux. It builds on an earlier study (1) examining stream flow reactions to solar flux. Stream flow levels are dependent on cyclonic system frequency; solar flux levels are linked to cyclonic systems according to the mechanism described in (2). The river index is a weighted average of river level measurements published by the U.S. Geological Survey (USGS) (3). They are compared to the F10.7 centimeter (2800 MHz) solar flux (4). The general assumption made for this comparison is that increased solar flux levels intensify cyclonic, precipitation producing systems (1) which, after a delay for drainage, result in increased river system stream flow. F10.7 cm solar flux increases are expected to result in similar, delayed stream flow index increases. Graphical data summaries and corresponding observations relating to the solar-terrestrial coupling mechanism, are presented below.

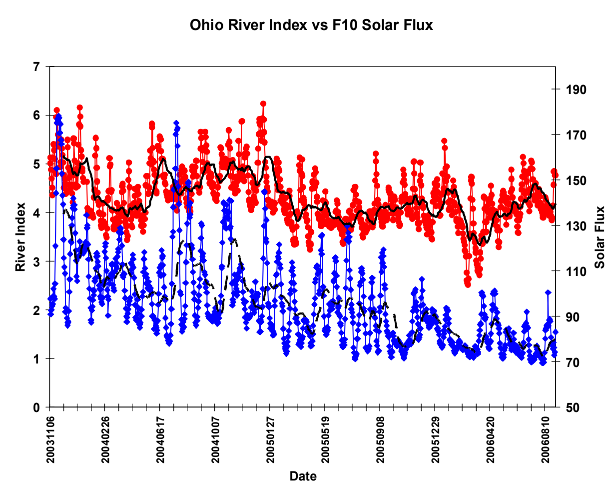
II. Data Analysis Results.

Study data were retrieved from the USGS website for the period January 16, 2001 (just after the last solar maximum in late 2000) through August 31, 2006 (near solar minimum in late 2006). Solar flux levels were plotted against river indices for three watershed regions: the Lower Mississippi, the Ohio, and the Missouri Rivers. Figures 1a through 3f are regional time-series plots.

In all six plots above a trendline, showing the 28-day moving average, is included for both the stream flow index (red plots) and the solar flux level (blue plots). Trendlines provide a more accurate comparison of fluctuations in the average stream flow index and the 28-day solar flux cycle. Based on the general assumption outlined above, comparison between the two trend plots should show solar flux increases resulting in delayed increases in the river index. The response behavior is less apparent in the second graph for each stream flow regime, for the period from 2003-2006. Solar flux levels were trending downward in the second half of the study; solar flux data fluctuated minimally throughout the ramp-down phase of the study period.



Figures 1a and 1b. Comparison between Ohio River river index (red plot) and solar flux level (blue plot) for 2001-2003 (top) and 2003-2006 (bottom).



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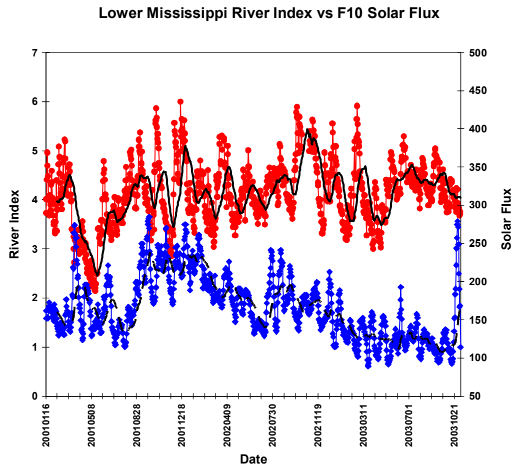


Figure 2a. Comparison between Lower Mississippi River river index (red) and solar flux (blue) for 2001-2003.

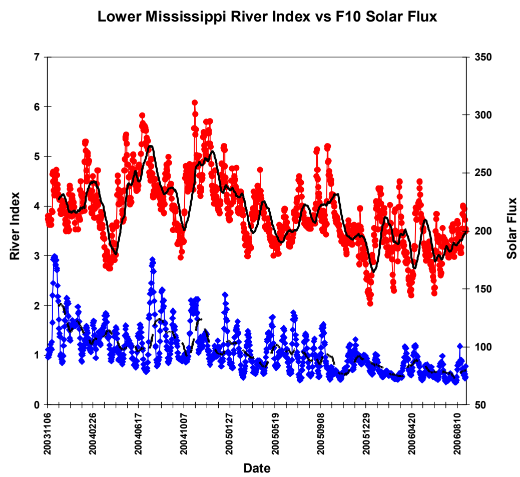
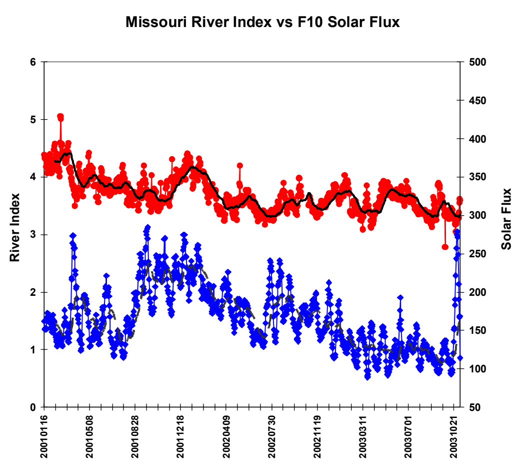


Figure 2b. Comparison between Lower Mississippi River river index (red) and solar flux (blue) for 2003-2006.



Figures 3a. Comparison between Missouri River river index (red) and solar flux (blue) for 2001-2003 (above).

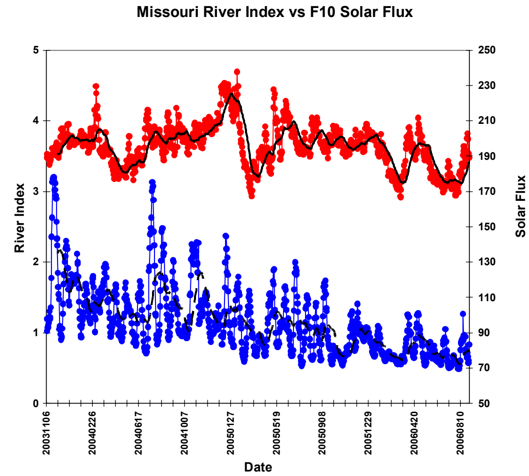


Figure 3b. Comparison between Missouri River river index (red) and solar flux (blue) for 2003-2006.

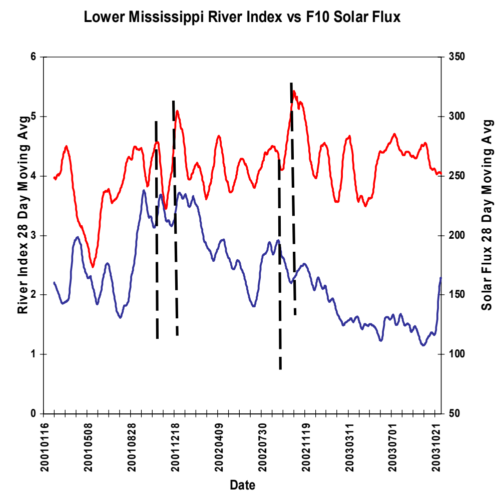


Figure 4a. Lower Mississippi trendline plots of river index red) and solar flux level (blue). Trend plots are based on a 28-day moving average for each parameter.

Figure 4a shows a comparison between the two trendline plots (28-day moving average) from the Lower Mississippi watershed region. The plots indicate the lag period shown by the distance between the two dashed lines is roughly equal to the distance between the X-axis tick marks (tick mark interval is 28 days). The area between the two dotted lines shows the stream flow response to solar flux changes, according to the above assumptions.

Figures 4b and 4c show the same data plots and comparisons for the Ohio River and Missouri River watersheds. Figures 4a, 4b, and 4c all illustrate data from 2001 through 2003, roughly coincident with solar activity from the latest solar maximum. Solar activity levels start to decrease from 2002 through 2003.

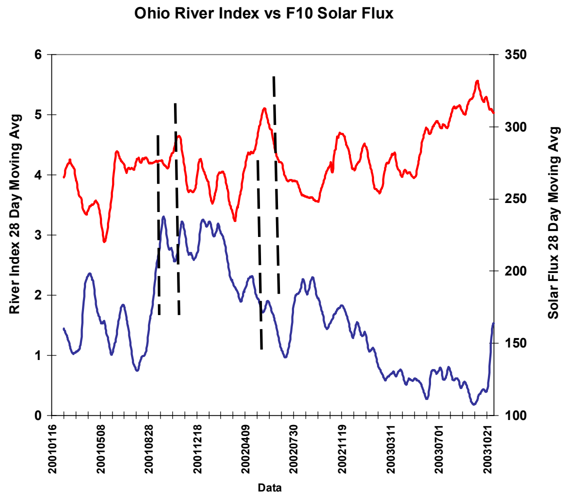


Figure 4b. Ohio River trendline plots of river index (red) and solar flux level (blue). Trend plots are based on a 28-day moving average for each parameter.

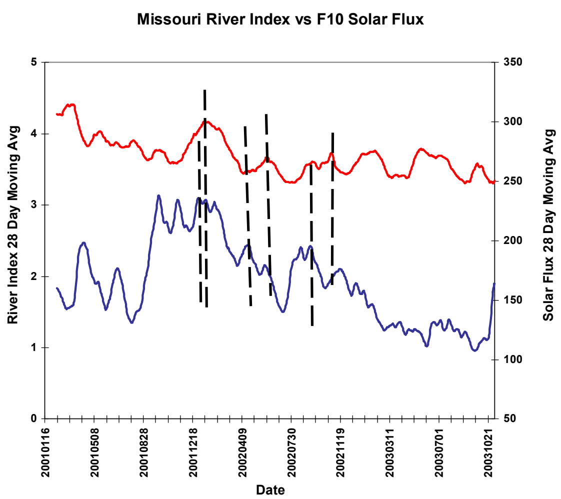


Figure 4c. Missouri River trendline plots of river index (red) and solar flux level (blue). Trend plots are based on a 28-day moving average for each parameter.

A comparison of Figures 4b and 4c show many of the same characteristics as in Figure 4a, with solar flux spikes followed by similar river index spikes. This is indicated by the time period between the two bold dotted lines However, the period when this relationship has the best agreement is different for the three river regions. In figure 4b the relationship between the solar flux level and the river index is more random throughout the 2001-2003 study period; the Missouri River watershed river index appears to react differently to solar activity fluctuations than the Ohio River or Lower Mississippi. This difference, as well as the period differences between the Ohio and Lower Mississippi River watershed plots, could be due to several factors. Factors to consider include: the number storm tracks hitting all three watershed regions, travel time required for a storm affecting more than one watershed region to move from one region to the next, storms that stall out or dwell over a watershed region, and the changes in storm strength and precipitation potential as the storm develops and moves.

The plots in Figures 4a, 4b, and 4c share a trait: a primary solar flux maximum precedes a primary river index maximum. These characteristics are present in the plots for all three watershed regions and are identified by thin dashed vertical lines. This correlation indicates a seasonal or long-term solar flux increase leads to a river index increase. An additional implication of this preliminary observation is that the rise in solar flux induces a subsequent period of more frequent, precipitation-producing cyclonic systems over these watershed regions, thus producing an increase in the river index. However, a closer examination of the Lower Mississippi and Missouri region plots shows that while only one primary maximum for solar flux level occurs during the study period, the plots for river index show multiple, major maxima. Inconsistencies between the 112-day moving average plots imply a more comprehensive and directed study is necessary to define whether a seasonal relationship exists between the two parameters. Though this study covered a time period encompassing part of both a solar maximum period and a ramp down toward solar minimum, a study encompassing an entire solar cycle would be more illustrative.

In approach to solar minimum (late 2006), there appears to be a diminishing correlation between solar flux variations and river reactions. Figures 5a through 5c show river indices and solar flux values plotted for late 2003 through late 2006. As solar minimum is approached background solar flux levels trend downward, but isolated violent fluctuations in solar flux levels are still evidenced. There is a general overall downward trend in both the solar flux levels and river indices, as shown in figures 5a through 5c.

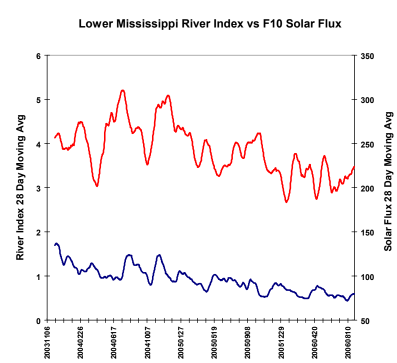


Figure 5a. Lower Mississippi River 28 day moving average trendline plots: River Index (red) and Solar Flux (blue)

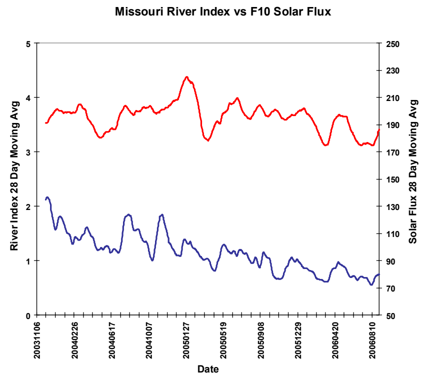


Figure 5b. Missouri River 28 day moving average trendline plots: River Index (red) and Solar Flux (blue)

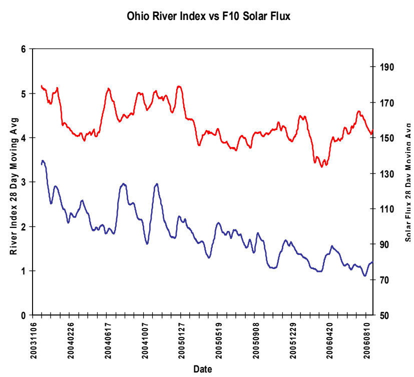


Figure 5c. Ohio River 28 day moving average trendline plots: River Index (red) and Solar Flux (blue)

One method for minimizing individual storm influences is to average data over a longer time-scale while analyzing the data to uncover a relationship between the solar flux and watershed levels. Figures 6a through 6c show this seasonal comparison. These plots employed a 112-day moving average of both parameters over the full study period for the same three watershed regions. One influence not examined in this paper is the influence of the Quasi-biennial Oscillation (QBO) (5). Since the QBO influences the frequency and intensity of cyclonic systems according to (5), changes in the QBO coupled with changes in the solar flux may also affect the river index for a given watershed region.

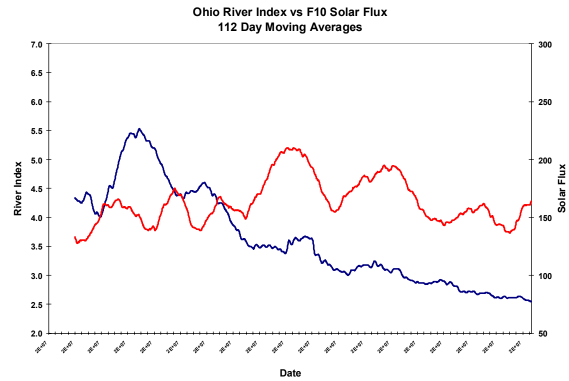


Figure 6a. Ohio River watershed 112-day moving averages of River Index (red) and Solar Flux (blue) over entire study period.

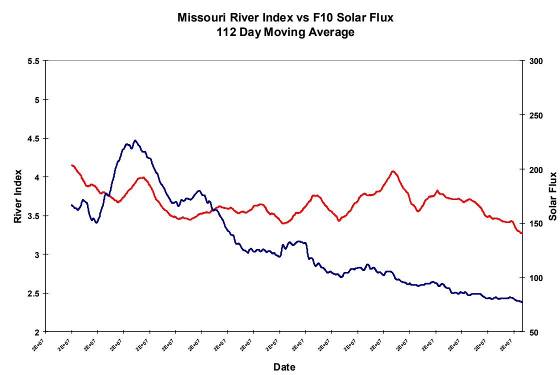


Figure 6b. Missouri River watershed 112-day moving averages of River Index (red) and Solar Flux (blue) over entire study period.

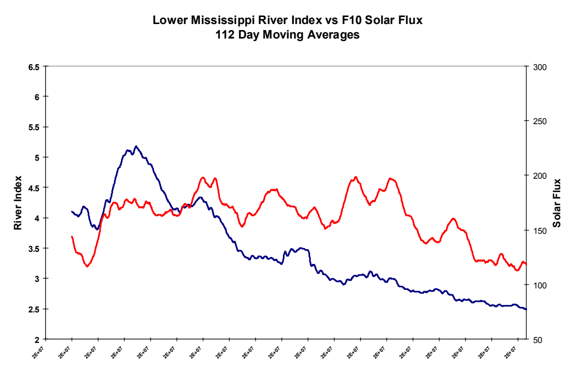


Figure 6c. Lower Mississippi River watershed 112-day moving averages of River Index (red) and Solar Flux (blue) over entire study period.

III. Study Conclusions.

The results of this study provided comparisons between river index and solar flux levels for three watershed regions over a 5 1/2 year period. Plots were generated for both parameters using 28-day and 112-day moving averages. When the plots were evaluated against the initial assumption, different conclusions were reached for each specific moving average. A summary of the conclusions is provided below.

1. The 28-day moving average plots show the best agreement with the initial assumption that a river index increase follows a solar flux increase. A possible explanation for this conformity is the 28-day solar flux cycle and related mechanism described in (2). The agreement is best seen in the Lower Mississippi and Ohio watershed regions where a spike or dip in the solar flux regularly precedes a corresponding spike or dip in the river index. However, the time period of these occurrences differs per region. In addition, although the Missouri River watershed shows some of the same characteristics seen in the other two regions, there is less consistency in the relationship between the 28-day moving average plots for the two parameters over any portion of the study period.

2. Plots generated with a 112-day moving average show a general trend in both the solar flux and river index levels, with an overall downward trend in both parameters toward the end of the study period. However, a spike in solar flux level preceding a spike in the river index level is not observed in these plots. The Ohio and Lower Mississippi River plots show more commonality of behavior; Missouri River watershed plots are somewhat distinct in behavior from the other two.

3. There are indications from both the 28-day and 112-day moving average plots that a study covering a much longer time span would provide more conclusive results, preferably covering at least an entire solar cycle. A longer study period may provide information regarding repetitive patterns of agreement or disagreement with the initial assumption, or that an alternative hypothesis is necessary.

4. This study covered three distinct watershed regions. However, these watershed regions are interrelated; the Ohio and Missouri River watershed regions feed the Lower Mississippi River region. Observances for regional plots were inconclusive. The most consistent similarities were for the Ohio and Lower Mississippi River regions; they may result from these two regions being positioned on the same general storm track. This trend requires further study.

5. There also should be a consideration of the fact that there is some water level management over portions of these watersheds. This can alter drainage patterns and affect stream gauge measurements, thereby affecting river index values. This was somewhat overcome by using a weighted average for the river indices. But the effects of water management on stream flow values were not quantified or taken into account in this study

IV. Summary.

This study indicated a general relationship between the 28-day moving average plots of river index and solar flux level exists for the three watershed regions. The relationship, based on an initial assumption for the response of river index to solar flux level, was not observed for the 112-day moving average plots. In addition, the relationship during the study period was not entirely consistent for all three watershed regions for either the 28-day or 112-day moving averages. A longer study period would likely yield more conclusive results.

Potential areas indicated for further study include the following considerations: (1) whether the precipitation-producing cyclonic systems affect more than one region; (2) examination of other indices for measuring stream flow response to cyclonic activity in a region; (3) study of other watersheds for discovery of similar affects; (4) investigating the geomorphology of each region as a factor affecting the river index, (5) looking at the amount of water management over a watershed, and (6) analyzing data over at least an entire solar cycle. These considerations for additional study also apply to other world regions to determine if there is a continental or hemispheric variation.

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